O. E. S. Doc. 9.

UNITED STATES DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS.

CIRCULAR NO. 8.

EXPLANATIONS AND DIRECTIONS

FOR

SOIL TESTS WITH FERTILIZERS.

MARCH, 1889.

20646—No. 8

Plan of experimental field.

Field.—Length, 213 feet 4 inches; width, 204 feet; area, 43,520 square feet. (One acre is 43,560 square feet.)

Plots.—Length, 204 feet; width, 10 feet 8 inches; area, 2,176 square feet. (One-twentieth of an acre is 2,178 square feet.)

Strips between and outside the experimental plots.—Length, 204 feet; width, 3 feet 4 inches.

The fifteen plots here provided for (10 manured and 5 unmanured), with the sixteen strips outside and between the plots, make together 40 square feet less than an acre. If one of the outside strips be made 3 feet 6 inches instead of 3 feet 4 inches, the whole will be 43,554 square feet, or 8 square feet less than an acre.

1. Nothing.
2. Nitrate of soda.
3. Dissolved bone-black.
4. Nothing.
5. Muriate of potash.
6. Nitrate of soda and bone-black.
7. Nitrate of soda and muriate of potash.
8. Nothing.
9. Bone-black and muriate of potash.
10. Nitrate of soda, bone-black, and muriate of potash.
11. Land plaster.
12. Nothing.
13. Barn-yard manure.
14. Lime.
15. Nothing.

The width of the plots, 10 feet 8 inches, has been found in practice convenient for use of machinery for planting corn and potatoes, sowing wheat, and harvesting wheat and grass.

TO BE TAKEN INTO THE FIELD.

CONDENSED DIRECTIONS.

(1) Have your plans all made and everything ready before you start. Remember that worn-out soil for the soil tests, uniform soil for all, plots long and narrow and accurately measured and staked out, and right application of the fertilizers are essential to the best success. Don't forget the tape or pole for measuring the plots, the scales for weighing, and the pail for carrying the fertilizers, and the stakes (four for each plot).

(2) Select a fair average portion of the field to be tested and lay it out as accurately as you can. Leave an unmanured strip at least 3 feet wide between each two plots, to prevent the roots of the plants from feeding on their neighbors' fertilizers.

(3) Designate each plot by a number according to the diagram on the back of this leaf. Put a strong stake firmly into the ground at each corner of each plot, and mark it with the number of the plot. If the plots are not staked and marked before the fertilizers are applied, you will risk making mistakes. When the fertilizer is applied to a plot, take the tag from the bag and fasten it to one of the stakes for a label.

(4) Distribute each fertilizer evenly over its plot, and do not let it get outside. Lay your plans for doing this in advance, otherwise you may find the fertilizer all used up before you get to the end, or have some left over. Remember what was said about mixing well with the soil. If you do not you may kill some of the seed and injure the growth of the rest.

(5) Be as systematic and accurate as you can, not only in starting the experiments, but in carrying them out, harvesting and measuring the produce, and noting the results.

The following figures will be of service in calculating the dimensions of the experimental plots and field: To calculate the size of plot of $\frac{1}{20}$ acre, find in the left-hand column, "width," the figure for the width decided upon; the opposite figure in the right-hand column will represent the length. Or, given the length in the right-hand column, the opposite figure in the left-hand column will be the width. For $\frac{1}{10}$-acre plots, take, of course, double the given length for same width or double the given width for same length.

One-twentieth-acre plots, width and length.

Assumed width.	Required length.	Assumed width.	Required length.
Rods:	*Feet. Rods. Ft.*	Rods:	*Feet. Rods. Ft.*
One-third	396 = 24 00	Two-thirds	198 = 12 00
Two-fifths	330 = 20 00	Three-fourths	176 = 10 11
One-half	264 = 16 00	Four-fifths	165 = 10 00
Three-fifths	220 = 13 5½	One	132 = 8 00
Feet:		Feet:	
6	363 = 22 00	11½	189 = 11 8
6½	335 = 20 5	12	182 = 11 00
7	312 = 18 14	12⅔	174 = 10 9
7½	291 = 17 10	13	168 = 10 3
8	273 = 16 8	13⅓	161 = 9 13
8½	257 = 15 9	14	155 = 9 7
9	242 = 14 10	14½	150 = 9 2
9½	230 = 15 15	15	145 = 8 13
10	218 = 13 4	15½	141 = 8 8
10½	208 = 12 9	16	136 = 8 4
11	198 = 12 00	16½	132 = 8 00

EXPLANATIONS AND DIRECTIONS FOR EXPERIMENTS.

SOIL TESTS WITH FERTILIZERS.

The object of these experiments is to enable farmers to study the needs of their soils and the action of fertilizers. Experience in the field, explained by experiments in the laboratory, has clearly demonstrated that:

(1) Soils vary greatly in their capabilities of supplying food to crops. Different ingredients are deficient in different soils. The way to learn what materials are proper in a given case is by observation and experiment. The rational method for determining what ingredients of plant-food a soil fails to furnish in abundance, and how these lacking materials can be most economically supplied, is to put the question to the soil with different fertilizing materials and get the reply in the crops produced.

(2) The chief use of fertilizers is to supply plant-food. It is good farming to make the most of the natural resources of the soil and of the manures produced on the farm, and to depend upon artificial fertilizers only to furnish what more is needed. It is not good economy to pay high prices for materials which the soil may itself yield, but it is good economy to supply the lacking ones in the cheapest way. The rule in the purchase of costly commercial fertilizers should be to select those that supply, in the best forms and at the lowest cost, the plant-food which the crop needs and the soil fails to furnish.

(3) The only ingredients of plant-food which we ordinarily need to consider in fertilizers are potash, lime, sulphuric acid, phosphoric acid, and nitrogen. The available supply of sulphuric acid and lime is often insufficient; hence one reason for the good effect so often observed from the application of lime, and of plaster, which is a compound of lime and sulphuric acid. The remaining substances, *phosporic acid*, *potash*, and *nitrogen*, are the most important ingredients of our common commercial fertilizers, because of both their scarcity in the soil and their high cost. It is in supplying these that phosphates, bone manures, potash salts, guano, nitrate of soda, and most other commercial fertilizers are chiefly useful.

(4) Plants differ widely with respect to their capacities for gathering their food from soil and air; hence the proper fertilizer in a given case depends upon the crop as well as upon the soil.

(5) The results of any given experiment are, in the main, applicable only to the particular case where it is made.

(6) A single season's experimenting does not tell the whole story. To get complete results the trials must be carried through a series of years and crops.

(7) Of course, such experiments may at best fall short of their purpose. Other factors than the plant-food in fertilizers help to decide their value. Soils fail to furnish enough food to crops, not so much because they have not abundant stores as because the materials are not in available forms. The indirect action of fertilizers in improving the mechanical condition of the soil, increasing its absorptive power, and rendering its inert stores of plant-food available, is often of much more consequence than their direct action in supplying plant-food. Hence cheap materials, like lime and plaster, are sometimes more profitable than the costlier chemical fertilizers or even farm manures. Often the lack of fertility of a soil is due not so much to its lack of plant-food as to its physical condition, its texture, and its relations to heat and moisture; or to its lack of absorptive power, the power to hold plant-food, and not allow it to be leached away beyond the reach of the roots of the plants. Such soils want amendments first and fertilizers afterwards. Tillage improves the mechanical condition of the soil, while it also aids in rendering plant-food available. Sometimes tillage is even more important than manure.

(8) The success of experiments with different fertilizing materials as tests of the wants of soils is often impaired by the physical conditions just named, and oftener by two very common sources of error—inequalities of soil and accumulated stores of plant-food in the soil. Land of uniform quality is essential for these experiments. By continued cropping and fertilizing in certain ways soils sometimes become overstocked with some forms of plant-food and deficient in others. These tests are useful in helping to find how to restore the balance in such cases. When the object is to find not what the soil can do with the aid of plant-food left over from past manuring and culture, but what it can furnish from its own resources—in other words, when the natural strength of the soil is to be tested—it is important to select fields worn out by long cropping without manure.

FERTILIZERS USED FOR SOIL TESTS.

Since the ingredients of plant-food of which worn-out soils most commonly fail to supply enough to produce profitable crops are nitrogen, phosphoric acid, and potash, standard commercial materials containing these are used for the experiments. Nitrate of soda, of about 95 per cent purity, containing 16 per cent of nitrogen; dissolved bone-black (superphosphate) with about 16 per cent of phosphoric acid, besides sulphuric acid and lime, and muriate of potash of 80 per cent purity containing some 50 per cent of "actual potash," are employed. These are applied singly, two by two, and all three together, on the different plots. Besides these, plaster (high-grade gypsum) is also used, not only

to furnish sulphate of lime to counterbalance that in the superphosphate, but also because of its fertilizing action, which is often very considerable. The materials are put up in bags intended for one-twentieth of an acre. The eight bags thus suffice for eight plots, which, with two unmanured plots, make half an acre. With plots for other fertilizers, unmanured strips between the plots to prevent the plants of one plot from feeding on the fertilizers of the adjoining plots, the experiment will cover considerably more land. The kinds and quantities of materials and of valuable ingredients per plot and per acre are shown herewith:

Experimental fertilizers for soil tests.

Fertilizing materials.			Valuable ingredients.	
Kinds.	Amount per plot.	Amount per acre.	Kinds.	Amount per acre.
	Pounds.	*Pounds.*		*Pounds.*
Nitrate of soda	8	160	Nitrogen	26
Dissolved bone-black	16	320	Phosphoric acid	51
Muriate of potash	8	160	Potash	80
Nitrate of soda	8	160	Nitrogen	26
Dissolved bone-black	16	320	Phosphoric acid	51
Nitrate of soda	8	160	Nitrogen	26
Muriate of potash	8	160	Potash	80
Dissolved bone-black	16	320	Phosphoric acid	51
Muriate of potash	8	160	Potash	80
Nitrate of soda	8	160	Nitrogen	26
Dissolved bone-black	16	320	Phosphoric acid	51
Muriate of potash	8	160	Potash	80
Plaster	8	160		

Besides these it will be well to test the action of farm manures, lime, and other fertilizing materials.

GENERAL DIRECTIONS FOR SOIL TEST EXPERIMENTS.

While the station will do all it can by printed explanations and directions and by the presence and help of its representatives, it especially requests the experimenter to bestow upon the experiments his most thoughtful attention and accurate work. It invites particular attention to the following directions:

"What is worth doing is worth doing well." In furtherance of the purpose of the experiment and its best execution, please note:

The "Condensed directions."—This slip is intended to be taken into the field for use in laying out the experiment.

The blank for report.—This will be furnished by the station. Please look it over while the crop is growing, consider what it asks for, and make up your mind how to collect the facts. If ways of improving the plan occur to you, please suggest them, and, if agreed to on consultation, adopt them, and at any rate accept thanks.

EVERYTHING IN ORDER BEFORE STARTING.

(1) Have your plans complete and clearly in mind, and everything ready before you start. Proper plans at the outset; uniform soil for all the experiments; "worn-out" soils for the soil tests; plots of proper size, shape, and accurately laid out; right application of the fertilizers; good seed; careful measurement of crops; full notes of details; and careful observation of the effects of the fertilizers on succeeding crops, are essential to the best results.

CONVENIENCIES.

(2) It will be well to have at hand, in planting, a small spring balance and a light bucket or coal-hod. With these it is easy to weigh out the fertilizers from the bags, divide the contents of each bag into portions for one or more square rods each, and carry these portions of the fertilizers to corresponding portions of the plot, on which they can be spread. This will greatly help in uniform spreading.

At harvest you will need a scale, and, for such crops as potatoes, a basket holding at least two or three pecks, to determine the quantity of the crop. The produce on each plot can be divided by square rods, and thus weighed and measured in small portions.

A small note-book will be needed to take into the field during the season and put down observations as made. From this you can copy all you wish to preserve in a more substantial book at your leisure.

UNIFORM SOIL.

(3) The soil should be as nearly uniform in quality as possible. There will be more or less variation in different parts of the same field at best. The less there is of this the more reliable will be the experiment. Level land should be chosen if practicable, but if it is sloping, let the plots run up and down the ascent, so that wash by rains will not transfer the materials from one plot to another. Of course the portion chosen for experiment should be a fair sample of the whole field.

KIND OF SOILS FOR TESTS.

(4) The action of the different fertilizers will be most clearly shown on soils that are more or less worn down by culture. To learn what the soil itself can do by its own natural strength, rather than what it will do with the aid of a store of plant food which has been accumulated by natural processes or left over from previous manuring and will obscure the action of the fertilizers, it is important to select worn-out soils. On soils in high condition the results of such tests are apt to be unsatisfactory. At the same time, land which has been generously treated with certain kinds of manures or artificial fertilizers may still be unsuited to certain crops, and tests of soils of this class may give very valuable results.

LAY OUT PLOTS ACCURATELY.

(5) Lay out the whole experimental area and the individual plots as accurately as you can. Measure with chain or tape, if you have it; otherwise with pole marked in feet and inches. Drive good strong stakes firmly into the ground at the boundaries, so that you may be able to tell in this and coming seasons where the divisions are. There should be four stakes for each plot, one at each corner. These will show the boundaries of the plots and of the unmanured space between them. The stake for each plot can be marked with the number of the plot. The marks can be cut in the stakes with a knife. The tag on the bag can be tied to one of the stakes of the plot to which it belongs.

SIZE AND SHAPE OF EXPERIMENTAL FIELD AND OF PLOTS.

(6) If the seed is to be planted in rows the length of the plots can be adapted to the distance of the rows apart. The "Condensed Directions" give figures which will help in calculating the dimensions of the plots and field. If the soil is even, small, short plots will do. But generally it will not be even, and long plots are therefore safer.

An unmanured strip at least 3 feet wide should be left between each two plots, so as to prevent the plants of one from being affected by the manure of another.

ARRANGEMENT OF PLOTS.

(7) The diagram herewith shows a convenient arrangement of plots. It provides for farm manures and lime in addition to the fertilizers of the experimental set. Of course these and other extra materials can be used at discretion. It is very important that several unmanured plots should be left for comparison. Experience justifies the number in this schedule. An even better test of the uniformity of the soil, however, is the duplication of fertilized plots where that is practicable.

Plan of experimental field.

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15. Nothing.

The width of the plots, 10 feet 8 inches, has been found in practice convenient for use of machinery for planting corn and potatoes, sowing wheat, and harvesting wheat and grass.

APPLICATION OF FERTILIZERS.

(8) The fertilizers should be—

First. Applied evenly over the plots where they belong, and not allowed to get outside.

Second. Well distributed through the soil.

Experiments with concentrated fertilizers are often spoiled, just as crops are injured or lost, through wrong application. Farmers are apt to think the manure must be put close to the seed or the plant will not get the benefit of it. This is wrong. It is not the just-germinated plantlet that needs the manure, but the plant, from the time it is well started until its growth is done. We want not only to give the crop a good start, but to help it out on the home-stretch as well. The roots and their branching rootlets run out in all directions in search of food, and the fertilizers ought to be where as many of the rootlets as possible can get at them. If we distribute the fertilizers as well as we can, the water in the soil, aided by the chemical and physical forces that nature keeps in operation, will do the rest. In illustration of this, remember how well barn manure acts when applied as a top-dressing long before the seed is put in.

But if we concentrate the fertilizers in one place, fewer roots will get them, and these may be injured by coming in contact with them or with their concentrated solutions in the soil. The roots will find their way to the manure and develop more where it lies, it is true; still we should not oblige them to huddle together in one place, but should rather encourage them to spread around, where, with the increased capacity the fertilizer gives them, they can get the more from the soil. Roots join with other natural agents in rendering inert stores of plant food available.

Above all, do not let the fertilizers come too close to the seed. A coarse, dilute material like yard manure may do the plants no harm, but such concentrated fertilizers as potash salts, nitrate of soda, dried blood, or high grade superphosphates may kill them. Since in these experiments it is particularly important that the effect of each fertilizer be fairly tested, it will be well to *mix them with three or four times their bulk of mellow earth before applying*, but this earth should be taken from the plot to which the fertilizer is applied. Moist sawdust, when obtainable, is apt to be more convenient. Do this by all means if applied in the hill or drill. When the plots are accurately staked out and the fertilizers carefully applied and worked in, the plow or harrow may be run across the plots without fear of transporting the fertilizers from one to another, provided the surface is free from stubble, litter, and clods.

SEE THAT ALL IS DONE RIGHTLY.

(9) Attend to the work yourself. Don't trust it to the hired man, unless you are sure he will do it better than you can.

MAKE ACCURATE OBSERVATIONS.

(10) Watch the experiments closely. Note your observations. Make them both as accurate and complete as you can. Put down your notes when you make your observations. Do not trust them to future recollection.

REPORTS.

(11) Make your reports as full and accurate as possible. Keep one copy for your own future use and send the other in, so that your results may be compared and published with others in good season. The benefit will not be yours alone, but you will share with others the good that will come from the combined work of all.

PLANS FOR CONTINUING THE EXPERIMENTS IN COMING YEARS.

To give the experiments their proper value they should be continued through a series of years with the same fertilizers on the same plots, and with either a rotation of crops or with the same crop year after year. It is hoped that a considerable number of the experiments may be thus repeated. For this the stakes bounding the plots must be kept in place.

THIS PROGRAMME IS NOT AS DIFFICULT AS IT SEEMS.

This may seem a pretty heavy programme for ordinary farmers. Of course the circumstances in which you work will require changes which your own good judgment will regulate.

Good things are not to be had without cost, and to those who have the spirit of the investigator—and there are very many who have that spirit—the task is pleasant and not burdensome. Some of the most accurate, thorough, and valuable field experiments ever made in this country have been carried out by farmers.

The following "condensed directions" are for use in the field:

CONDENSED DIRECTIONS.

(1) Have your plans all made and everything ready before you start. Remember that worn-out soil for the soil tests, uniform soil for all, plots long and narrow and accurately measured and staked out, and right application of the fertilizers are essential to the best success. Don't forget the tape or pole for measuring the plots, the scales for weighing, the pail for carrying the fertilizers, and the stakes (four for each plot).

(2) Select a fair average portion of the field to be tested and lay it out as accurately as you can. Leave an unmanured strip at least 3

eet wide between each two plots, to prevent the roots of the plants from feeding on their neighbors' fertilizers.

(3) Designate each plot by a number, as suggested in the diagrams, and corresponding to the number of the fertilizer. Put a strong stake firmly into the ground at each corner of each plot, and mark it with the number of the plot. If the plots are not staked and marked before the fertilizers are applied, you will risk making mistakes. When the fertilizer is applied to a plot, take the tag from the bag and fasten it to one of the stakes for a label.

(4) Distribute each fertilizer evenly over its plot, and do not let it get outside. Lay your plans for doing this in advance, otherwise you may find the fertilizer all used up before you get to the end, or have some left over. Remember what was said about mixing well with the soil, especially when it is put near the seed. If you do not, you may kill some of the seed and injure the growth of the rest.

(5) Be as systematic and accurate as you can, not only in starting the experiments, but in carrying them out, harvesting and measuring the produce and noting the results.

The following figures will be of service in calculating the dimensions of the experimental plots and field. To calculate the size of plot of one-twentieth of an acre, find in the left-hand column, "Width," the figure for the width decided upon; the opposite figure in the right-hand column will represent the length. Or, given the length in the right-hand column, the opposite figure in the left-hand column will be the width. For one-tenth acre plots, of course take double the given length for same width, or double the given width for same length.

One-twentieth-acre plots, width and length.

Assumed width.	Required length.			Assumed width.	Required length.		
Rods:	*Feet.*	*Rods.*	*Ft.*	Rods:	*Feet.*	*Rods.*	*Ft.*
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Two-fifths	330	= 20	00	Three-fourths	176	= 10	11
One-half	264	= 16	00	Four-fifths	165	= 10	00
Three-fifths	220	= 13	5½	One	132	= 8	00
Feet:				Feet:			
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6½	335	= 20	5	12	182	= 11	00
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7½	291	= 17	10	13	168	= 10	3
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10½	208	= 12	9	16	136	= 8	4
11	198	= 12	00	16½	132	= 8	00